Comparison of SAR Tomography and phase histogram techniques for remote sensing of forested areas: an experimental study based on TomoSense data

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Introduction

Synthetic aperture radar (SAR) remote sensing has gained a prominent position concerning remote sensing of forest scenarios, largely due to its all-weather observation capabilities, large coverage, and accuracy. Long wavelength fully polarimetric SAR systems are particularly interesting concerning the exploration of the vertical structure of the illuminated media, like forests, ice, and snow, by virtue of the combination of penetration capabilities and sensitivity to different scattering mechanisms. SAR tomography (TomoSAR) technology can obtain three-dimensional vertical backscattering power distribution and reconstruct the vertical structure of the illuminated media. Different from the common SAR imaging mode, with the aid of a certain of SAR acquisitions, TomoSAR can resynthesize aperture perpendicular to the slant-range direction and providing a powerful technical tool for reconstructing the three-dimensional structure. That is also a key technology for the forthcoming Earth Explorer mission BIOMASS to map global forest height and above over ground biomass (AGB), as well as underlying topography. In this context, the TomoSense experiment was organized by the European Space Agency (ESA) to provide the scientific community with unprecedented data to study the features of radar scattering from temperate forests, comprising tomographic and fully polarimetric SAR surveys at P-, L-, and C-band, acquired in mono- and bistatic mode by simultaneously flying two aircraft. The data were acquired at the Kermeter site in the National Park Eifel in North-Rine Westphalia in Germany. The TomoSense dataset also includes Terrestrial Laser Scanning (TLS) and Airborne Lidar Scanning (ALS) products to provide a reliable reference for validation.

In this poster, we analyze TomoSense data to present an experimental study related to the use of two different approaches to structural analyses of forested areas. The first one consists in using multi-baseline data to form a tomographic reconstruction of the forest vertical profile, using well known methods from SAR tomographic processing. The second one takes advantage of the phase histogram approach, which under some circumstances allows for an estimation of forest structure using single-baseline data. The two approaches are here compared concerning their capability to correctly estimate forest structure and forest height.

Methodology

$$g(z_n)=\sum_{i=1}^{L}\omega_i f(s_1,s_2)\chi_i(z_n,\varphi_i)$$

$$\chi_i(z_n,\varphi_i)=\begin{cases}1, if\ \dfrac{\varphi_i}{kz_i}\ni z_n\pm\delta z\\ 0, \qquad others\end{cases}$$

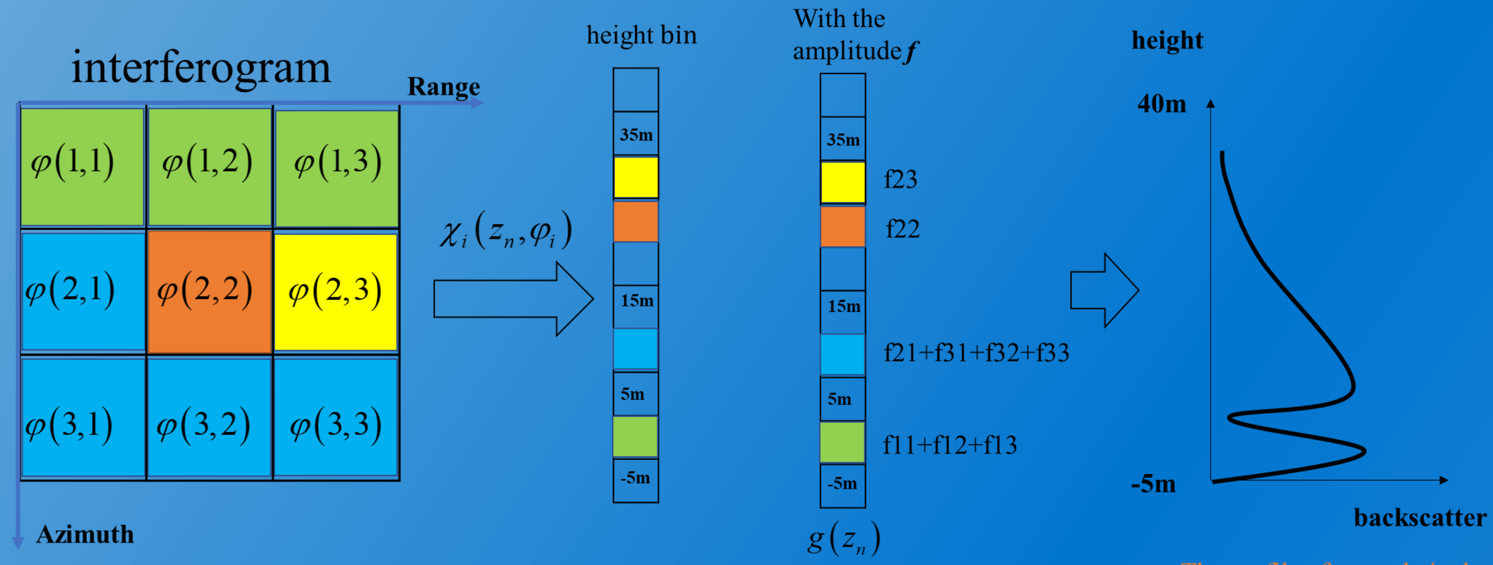
ω_i Weight factor

$f(s_1,s_2)=|s_1 s_2^*|$ amplitude

φ_i InSAR phase

kz Phase to height factor

z_n Height bin



The profile of central pixel

Distributed scatterer

$$SLC_m = A_g e^{j\cdot\varphi_g} + A_c e^{j\cdot\varphi_c}$$

$$SLC_s = A_g e^{j\cdot\varphi_g} e^{j\cdot kz\cdot z_g} + A_c e^{j\cdot\varphi_c} e^{j\cdot kz\cdot z_c}$$

$$SLC_m \bullet SLC_s^H = |A_g|^2 e^{-j\cdot kz\cdot z_g} + |A_c|^2 e^{-j\cdot kz\cdot z_c} + A_g A_c e^{j(\varphi_g-\varphi_c)} e^{-j\cdot kz\cdot z_c} + A_g A_c e^{j(\varphi_c-\varphi_g)} e^{-j\cdot kz\cdot z_g}$$

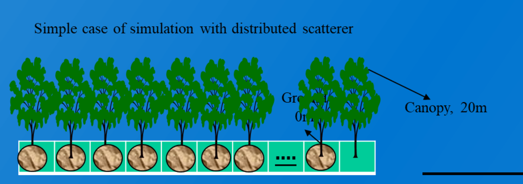
Dominant scatterer

$$SLC_m = Ae^{j\cdot\varphi}$$

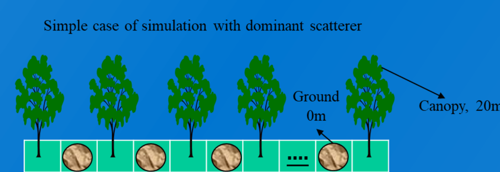
$$SLC_s = Ae^{j\cdot\varphi}e^{j\cdot kz\cdot z}$$

$$SLC_m \bullet SLC_s^H = |A|^2 e^{-j\cdot kz\cdot z}$$

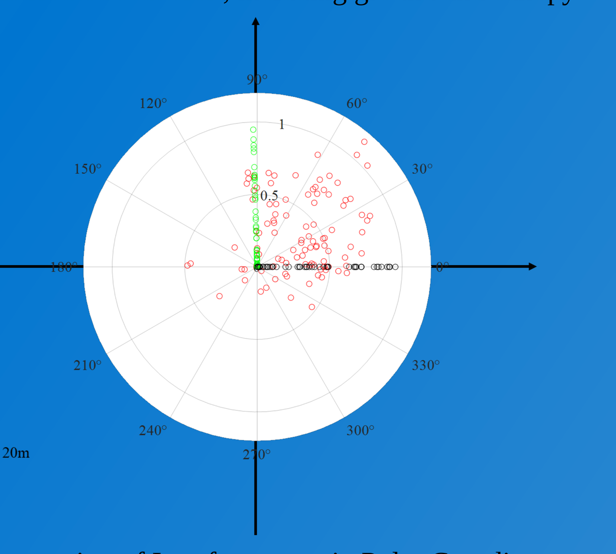
Simple case of simulation with distributed scatterer



Simple case of simulation with dominant scatterer



- Canopy, dominant scatterer
- Ground, dominant scatterer
- Distributed scatterer , including ground and canopy



Representation of Interferograms in Polar Coordinates

Simulations

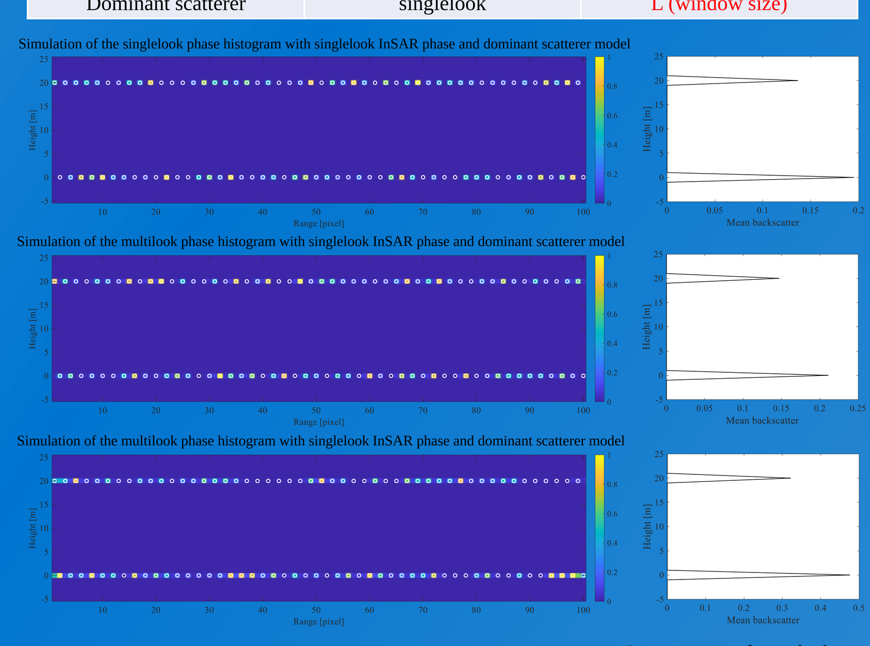
SLC model	InSAR-phase	Phase histogram
Dominant scatterer	singlelook	L (window size)

SLC model	InSAR-phase	Phase histogram
Dominant scatterer	L(window size)	L

singlelook

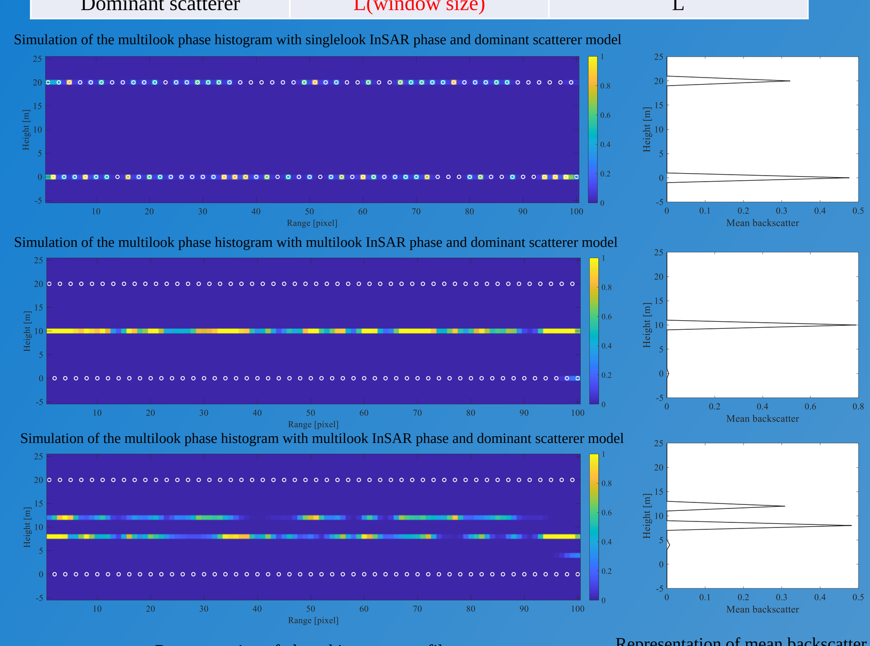
L =2

L =5



Representation of phase histogram profile

Representation of mean backscatter



Representation of phase histogram profile

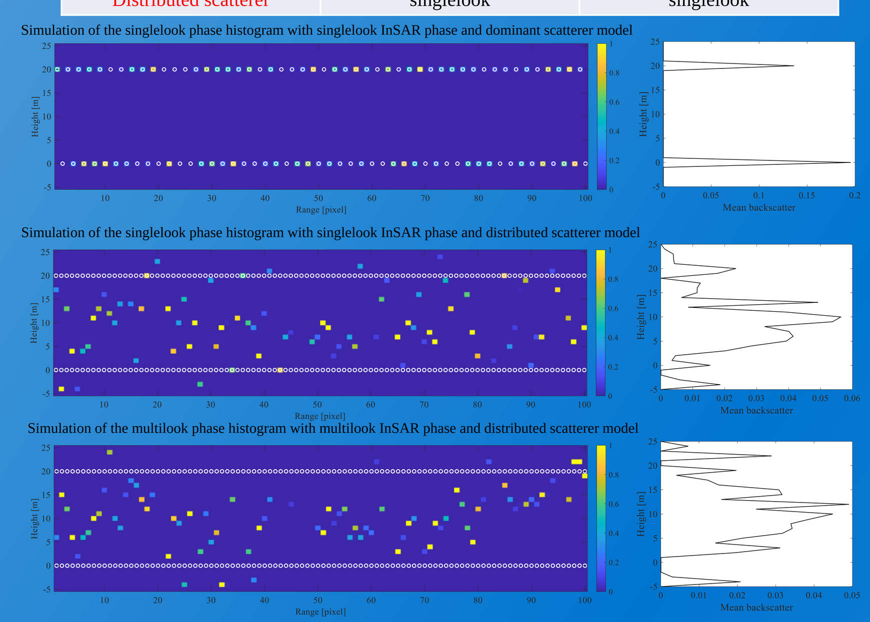
Representation of mean backscatter

SLC model	InSAR-phase	Phase histogram
Distributed scatterer	singlelook	singlelook

singlelook

L =2

L =5



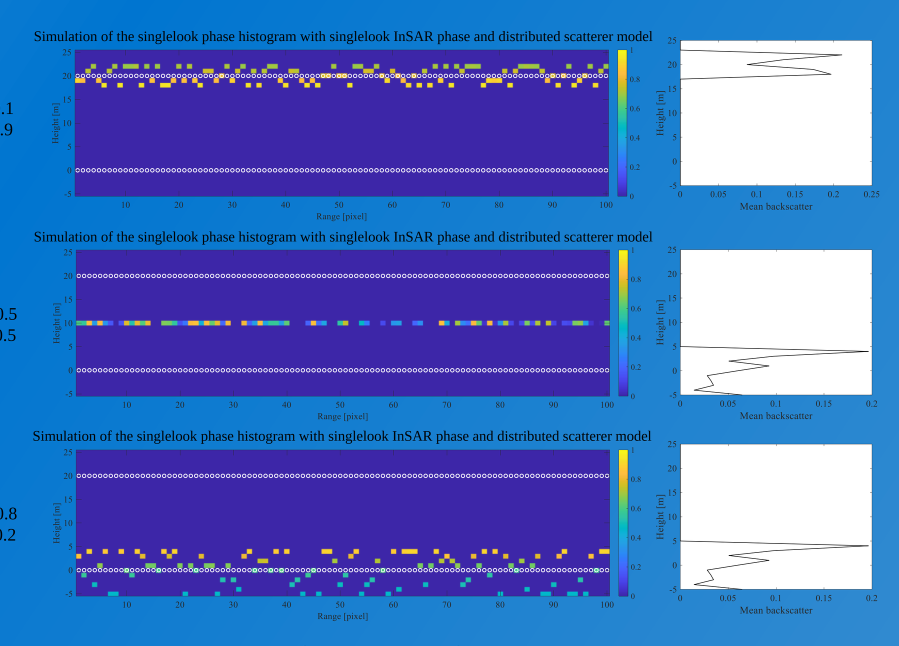
Representation of phase histogram profile

Representation of mean backscatter

Ag=0.1
Ac=0.9

Ag=0.5
Ac=0.5

Ag=0.8
Ac=0.2



Representation of phase histogram profile

Representation of mean backscatter

Case 1: single look InSAR phase, single/multi-look phase histogram， dominant scatterer
Fact: Phase histogram does work.

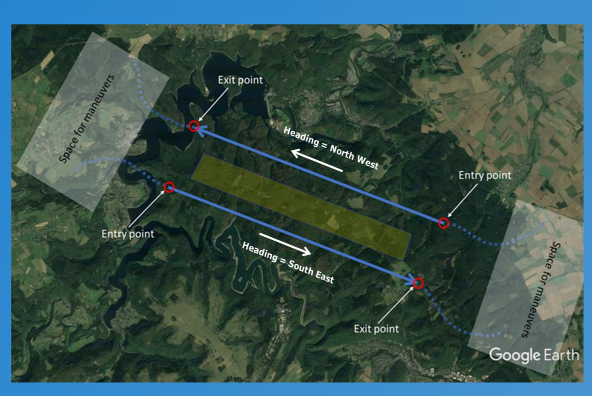
Case 2:multi-look InSAR phase, multi-look phase histogram, dominant scatterer
Fact: It will change the peak position and change the profile of phase histogram.
InSAR phase determines the positions of the scatters and *f* determines the contribution of scattered power.

Case 3: Distributed scatterers
Fact: Cluttered results, but will get the approximate correct results when there is only one dominant scatterer

Results

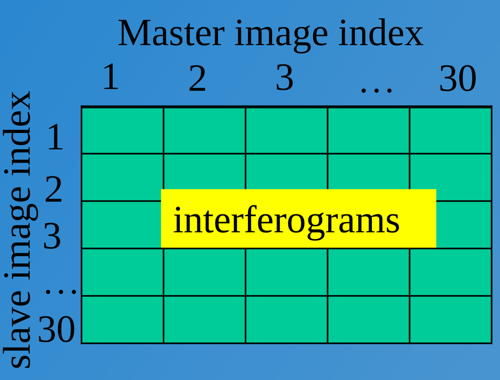
Monostatic L-Band dataset

Purpose	**Supporting future Synthetic Aperture Radar (SAR) mission concepts at P-, L-, and C-band by the European Space Agency (ESA). Providing a scientifical basis for the evaluation of single-pass interferometry over temperate forests at L- and C-band and investigate potential synergies between C-band convoy mission concepts and future P- and L-band missions.**
Band	P-band（monostatic，28 passes）; L-band（mono-/bi-static，30 passes）; C-band（mono-/bi-static，17 passes）
Study area	Eifel National Park in Germany
Fight plan	Polarimetric channels: HH/HV/VH/VV; Headings: NW (290°) and SE (110°)



Monostatic L-Band dataset

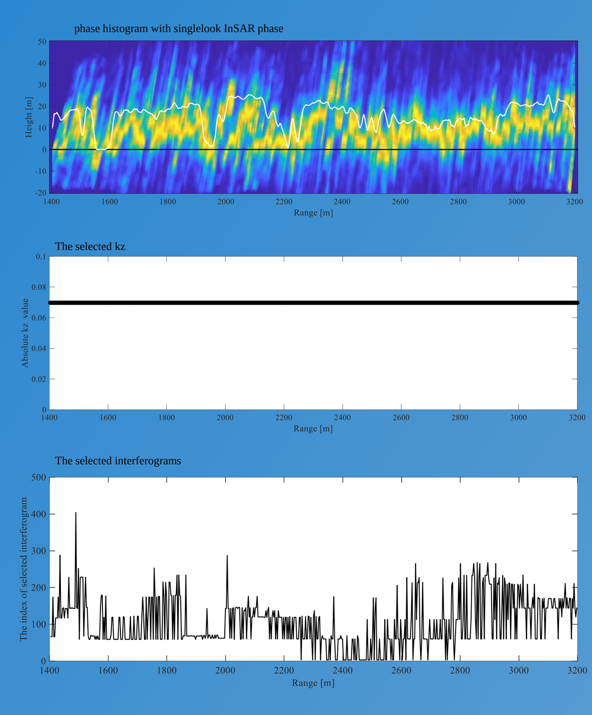
Parameter	Value
Number of repeat passes	30
Polarimetric channels	4
Headings	NW (290°) and SE (110°)
Wavelength	$22cm$
Bandwidth	$50MHz$
Slant range resolution	$3m$
Azimuth resolution	$55cm$
Vertical resolution ($-3dB, @30°$)	$1.3m$ (monostatic repeat-pass), $2.3m$ (bistatic repeat-pass)

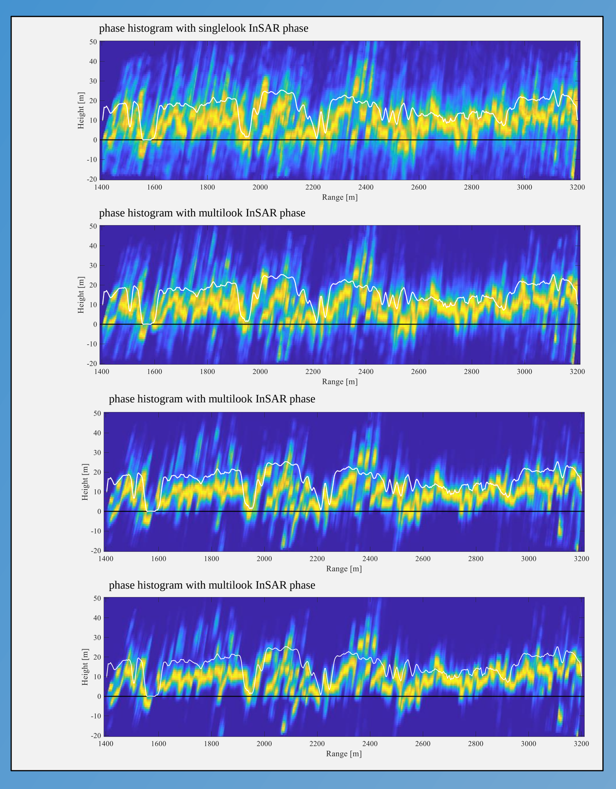


- **In total, 435 available interferograms**
- Constant kz interferogram

- Single baseline interferogram can not get the optimal phase histogram
- **Multi-baselines (435 pairs) phase histogram with all possible combinations**
- **The selection criterias:**
  If 80<HoA<120
  choose the minimum one;
  elseif HoA>120
  choose a min(HoA);
  else 80>HoA
  choose a max(HoA);
  end
- The setting parameters
  The phase histogram estimation window size: Az-rg:30x5 pixel
  The estimated window size of InSAR phase:

(A)Az-rg:1x1 pixel
(B)Az-rg:5x1 pixel
(C)Az-rg:15x1 pixel
(D)Az-rg:25x1 pixel





Conclusions

Conclusions

- Phase histogram technique dose only make sense under the assumption that there is only one dominant scatterer in a single pixel.
- As for airborne data, due to the bumpy flight, single baseline can not get an optimal phase histogram. Multi-baseline data are recommended to get a super resolution results.
- As for InSAR phase of phase histogram, multi-look process will remove some phase noise with loss of more detail of forest structure. The heterogeneity of the forest and the resolution of SAR images can also affect it.

Future work

- Explore the effect on the phase histogram with resolution of SLC
- Use Tomosense data for Forest height inversion by phase histogram

Reference

Shiroma G H X, Lavalle M. Digital terrain, surface, and canopy height models from InSAR backscatter-height histograms[J]. IEEE Transactions on Geoscience and Remote Sensing, 2020, 58(6): 3754-3777.

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